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PREDICTION OF EYE SAFE SEPARATION DISTANCES

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FOREWORD

This report was prepared in the Ophthalmology Branch under Project 6301, Task 630103 and under Program Element 6.16.46.01.D, Project 5710, Subtask 03.003, and was funded by the Defense Atomic Support Agency. The work was accomplished during January and February 1966 and was presented at the AGARD Symposium on Loss of Vision from High Intensity Light, NATO Building, Paris, France, 16-17 March 1966. The report was submitted for publication on 9 June 1966.

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This technical report has been reviewed and is approved for open publication by DOD (OASD/PA), #14, 2 March 1966.

ABSTRACT

A method is given for predicting the distances at which the thermal radiation from nuclear detonations will be hazardous to the unprotected human eye. This method relates calculated retinal exposure to experimentally determined eye effects data.

Eye hazards as a function of distance are determined for the unprotected human eye exposed to sea-level, air-burst detonations from 0.01 to 10 kt yield. The pupil diameter of the human eye is taken to be 2.5 mm. and 6.0 mm. respectively, for day and night conditions and the effective focal length of the eye is taken to be 17 mm. Nuclear detonation characteristics and scaling factors are taken from Glasstone's "The Effects of Nuclear Weapons". The results indicate that the eye hazard is the limiting factor in determining the distance of nearest approach to a nuclear detonation unless eye protection is provided.

Eye hazards as a function of distance are also determined for the human eye protected from daytime detonations by a 2% transmission fixed filter. The results indicate that use of such a filter will provide eye protection at distances where other hazards become limiting factors.

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I. INTRODUCTION

The thermal energy released in a nuclear detonation is sufficient to cause loss of vision in humans who view such detonations without eye protection. This loss of vision may be temporary, as in flashblindness, or permanent, as in retinal burns. The extent and duration of this loss of vision depend on the conditions of exposure.

The basic physical problem in the prediction of retinal burns is the determination of the increase of temperature in the retinal region in which the fireball is imaged. Areas in which the temperature, or time at some critical temperature, exceeds a certain value may be presumed to be irreversibly damaged. However, the nature of the problems and the difficulties in measuring and relating temperature profiles to functional effects have led to an approach by which observed retinal effects are associated with calculated retinal exposures. This approach is based on laboratory investigations which have established the dependence of ophthalmoscopically observable effects on total retinal exposure, retinal irradiance, and image size. The curves in figure 1 are based on the latest and most complete laboratory data available at this time (1).

A similar approach is used in estimating the duration of flashblindness following exposure to a nuclear detonation. Calculated retinal exposures appropriate to the flashblindness problem are related to laboratory investigations which have established the dependence of flashblindness duration on retinal exposure, illumination of the visual target following exposure, and visual acuity necessary to perform the required task (fig. 2) (2).

The use of these methods requires the calculation, from known source characteristics, of the retinal exposure, retinal irradiance, and image diameter associated with exposure to a nuclear detonation. The calculations are greatly simplified by using approximations of nuclear detonation characteristics.

II. CALCULATION OF RETINAL EXPOSURE

The retinal exposure resulting from viewing a nuclear detonation can be calculated if the exposure conditions are known. The effective radiant exposure, Q_r, of the retina may be expressed as

$$Q_r = \frac{10^{12} apkWT_e T_a T_x}{4\pi f^2 D_{fb}^2} \quad (cal/cm^2) \tag{1}$$

The average retinal irradiance, H_r, is simply

$$H_r = \frac{Q_r}{t} \quad (cal/cm^2\text{-}sec) \tag{2}$$

and the image diameter, D_i, is given by

$$D_i = \frac{FD_{fb}}{D} \quad (mm.) \tag{3}$$

where

$a = 0.8$ = Fraction of the thermal energy radiated which is located in the spectral region effective in producing retinal damage (350 mμ < Eλ < 1500 mμ assuming a 5800°K black-body radiator)

$p = 1/3$ = Fraction of total weapon yield converted to thermal energy (low-altitude detonations)

k = Fraction of thermal energy released during time t

W = Yield of the weapon in kilotons

$T_e = 0.8$ = Average transmission of clear media of the eye (assumed 5800° black-body spectrum) (3)

T_a = Average transmission of the atmosphere

T_x = Average transmission of any material between the eye and the detonation (i.e., aircraft canopy, sun glasses, filters)

$f = \frac{F}{D_p}$ = Ratio of the effective focal length of the eye-lens system to the diameter of the pupil

D_{fb} = Average fireball diameter in centimeters during exposure time t

t = Exposure time in seconds

D = Distance to fireball in centimeters

Retinal exposures have been calcualted, utilizing this method, for human eyes exposed to sea-level air-burst detonations from 0.01 kt to 10 kt, under both day and night conditions. In these calculations the effective focal length, F, and the bright daylight pupil diameter, D_p, of the human eye are taken to be 17 mm. and 2.5 mm., respectively, resulting in a value of $f = 6.8$. The nighttime pupil diameter is taken to be 6 mm., resulting in a value of $f = 2.83$, based on a recent investigation by Alder (4) in which he reports the average pupil diameter under dim cockpit conditions to be 5.9 mm.

The radiant power of a nuclear detonation is less than 45% of the maximum radiant power after an elapsed time of $2t_{max}$, and, along with the apparent surface temperature of the fireball, continues to decrease

rapidly. Thus, the energy effective in producing eye hazards is assumed to be radiated in a time $t = 2t_{max} = 0.064\ W^{0.5}$sec. This is assumed to be less than the blink reflex time for the yields considered here. During this period of time the fireball emits approximately 47% of the total energy radiated; thus, we have $k = 0.47$. The assumed average fireball diameter is that corresponding to t_{max} or $D_{fb} = 9.33 \times 10^3 W^{0.4}$cm. (Nuclear detonation characteristics are all from reference 5.)

Substituting the values above in equations 1, 2, and 3 gives the quantities listed in table I, which require only appropriate values for D, T_a, and T_x for the determinations of D_i, Q_r, and H_r.

Atmospheric transmission was calculated using the equation $T_a = \exp(-\kappa D)$, where D is the distance in km. and κ is an average extinction coefficient dependent on visibility. Transmission values were determined for three different conditions of visibility: 20 km. (κ= 0.20 km.$^{-1}$); 40 km. (κ= 0.10 km.$^{-1}$); and 80 km. (κ= 0.03 km.$^{-1}$) (5).

III. DISCUSSION

Retinal Burns

Image diameter, retinal exposure, and retinal irradiance were calculated for both day and night exposure conditions for each of the yields listed in table I, for each of the assumed visibilities, and for values of $T_x = 1$ (no intervening filters) and $T_x = 0.02$ (2% transmission fixed filter).

Figure 3 is a plot of retinal exposure and image diameter versus distance for daytime exposure to a 0.01 kt detonation for visibilities of 20, 40, and 80 km. with no filter and with a 2% fixed filter. Also shown in figure 3 is a plot of the threshold retinal exposure, Q_r^t,

required to produce a minimal retinal burn. Q_r^t for each distance was determined by using the exposure time and image diameter in conjunction with the threshold curves in figure 1. The distance at which Q_r^t exceeds the retinal exposure, Q_r, is the predicted threshold distance for minimal retinal burns. Figure 4 is a plot of the same information for nighttime exposure to a 0.01 kt detonation and figures 5 and 6 are similar plots for a 10 kt detonation.

This method was used to determine the threshold distance under both day and night exposure conditions and each assumed visibility for each yield listed in table I. Figure 7 is a plot of the threshold distance versus yield for the day exposures and figure 8 is a similar plot for the night exposures.

The threshold distance for a bright daylight exposure with clear air (80 km. visibility) varies from about 1.3 to 11 km. as the detonation yield varies from 0.01 to 10 kt. However, when the visibility is limited (20 km.), the threshold varies from about 1.1 to 4.6 km. for the same range of yields. Comparable distances for night exposures vary from 3.8 to 26 km. for clear air and 3.0 to 10.5 km. with limited visibility.

The use of a fixed filter with 2% transmission results in retinal exposures well below burn threshold values for each of the yields considered, as shown in figures 3,4,5, and 6. During daylight hours such a filter reduces the retinal exposure more than an order of magnitude below the threshold exposure. For nighttime conditions the retinal exposure is reduced by a factor of approximately 2.5 below the threshold exposure.

The threshold distances reported here are based on the assumption that the absorption properties of the human retina are essentially the same as those for a rabbit--as suggested by the absorption measurements of Geeraets, et al. (6). In addition, the curves in figure 1 show the thermal exposure which will produce a minimal burn, defined as a very slight coagulation of the retinal tissue which becomes ophthalmoscopically visible between 3 and 5 minutes after exposure (1,3,7). The exposure required to produce permanent damage is undoubtedly less than that required to produce burns defined in this way. However, there is as yet no satisfactory definition of minimum acceptable damage.

The threshold exposure curves in figure 1 are conservative in one respect, however. The energy spectrum of the source used in obtaining the data on which these curves are based was deficient in the infrared relative to a 5800°K black-body radiator (Fig. 9). Since the retina does not appear to absorb energy in the infrared as effectively as energy in the visible region of the spectrum (6), the threshold curves of figure 1 are somewhat lower than would be expected for a 5800°K black-body source--a source that in some respects resembles some nuclear detonations.

The predicted distances for minimal burns shown in figures 7 and 8 obviously cannot be interpreted as the distances at which humans may safely view nuclear detonations without eye protection. A safety factor needs to be introduced. However, the amount of this factor and how it should be introduced have not yet been arbitrated. One possibility is simply to lower the threshold curves for minimal burns by some arbitrary factor generally suggested to be between 5 and 10.

Once this factor is selected, it is only necessary to shift the ordinate scale of figure 1 to determine "safe" separation distances.

An increase in detonation altitude with the consequent increase in fireball diameter, energy emission rate, and atmospheric transmission (5) results in threshold distances greater than those shown here. The reader is cautioned against using these curves for other than sea-level air-burst conditions and for yields beyond the range spanned by these calculations. The basic method of calculation can be used for different detonation altitudes and other yields, but it may be necessary to consider different detonation characteristics for these conditions.

Flashblindness

The problem of attempting to predict the flashblindness caused by a nuclear detonation is complicated by a large number of variables with an almost infinite range of variations. Even when the range of possible detonation yields and altitudes is restricted to those considered here (0.01 to 10 kt sea-level air-burst detonations), different possibilities of cloud cover, position of the fireball in the field of view, light-scattering haze, etc., are innumerable.

The approach taken here assumes the worst case, i.e., direct (foveal) viewing of the fireball, and, by relating calculated exposures to laboratory data, determines the distances from the fireball at which recovery times of 5 sec. or less are predicted. Laboratory data indicate that a retinal exposure of 0.01 cal/cm^2 will result in a recovery time of approximately 5 sec. for a brightly lighted visual task (fig. 2). Retinal exposures for a variety of yields and

exposure conditions were calculated earlier in the determinations of the retinal burn hazard (figs. 3,4,5,6). These calculated exposures were used to determine the predicted distances for a retinal exposure of 0.01 cal//cm^2 for 0.01 to 10 kt detonations in bright daylight for the human eye protected by a 2% fixed filter. The results are shown in figure 10.

The predicted distance for a retinal exposure of 0.01 cal/cm^2 in clear air (80 km. visibility) varies from about 15 to 62 km. as the detonation yield varies from 0.01 to 10 kt. However, when the visibility is limited (20 km.) this predicted distance varies from about 2 to 9 km. for the same range of yields.

The recovery times shown in figure 2, however, are the times required by a subject to identify a 28.4 minute test letter (visual acuity 0.176) while looking through the afterimage caused by a bright flash of light subtending a visual angle of 10° and centered on the fovea (2). No attempt was made to determine the subject's ability to identify the test letter by using peripheral vision and "looking around" the afterimage. Weymouth et al. (8), however, report that the visual acuity 5° off the fovea is about 0.30, which certainly should be sufficient to identify a test letter requiring a visual acuity of only 0.176.

The author has personally viewed a standard altimeter at a distance of 76 cm. (30 inches)--average eye-to-instrument distance in fighter aircraft--following exposure to centrally fixated flashes of bright light. No difficulty was experienced in reading the altimeter when the afterimages subtended visual angles of 3° or less, even though individual numbers, when fixated directly, could not be identified

through the afterimages. As the visual angle subtended by the afterimages increased from 3°, the altimeter became increasingly difficult to read until, at 10°, a great deal of concentration and repeated peripheral scanning were required to determine the altitude to the nearest 100 feet. A pilot, however, cannot concentrate on a single instrument to the exclusion of all else.

Thus, rather arbitrarily, a centrally located afterimage subtending a visual angle of at least 3° was chosen as the condition necessary for a significant reduction in a pilot's ability to read his major flight instruments. An object which subtends a visual angle of 3°, however, produces a retinal image with a diameter of 0.9 mm. Therefore the pilot's ability to read his instruments should not be significantly affected by flashblindness when the afterimage has a diameter of less than 0.9 mm. The pilot probably would be able to maintain some control of his aircraft with afterimages greater than this by peripheral reference to the horizon. The distance from a nuclear detonation at which a fireball image diameter of 0.9 mm. would be produced varies from 0.28 to 4.5 km. as the yield varies from 0.01 to 10 kt (fig. 10).

To summarize briefly, a pilot viewing a small, daytime, low-altitude nuclear detonation through a 2% fixed filter would receive a retinal exposure of the order of 0.01 cal/cm^2 at the distances indicated in figure 10. At these distances, however, the afterimages would be less than 0.9 mm. and the pilot should be able to read his instruments without much difficulty. At distances less than those indicated by the 0.9 mm. line in figure 10, the pilot will experience increasing difficulty in reading his instruments but should be able to maintain

some control of his aircraft unless he is close enough to be within the lethal envelope of other effects. At distances inside the 0.01 cal/cm^2 lines, the pilot, although able to control his aircraft, would not be able to perform a task requiring central visual acuity for at least 5 sec. after exposure.

The curves in figure 10 are applicable only under the conditions specified here. The retinal exposures from night detonations or day detonations without eye protection exceed the limits of laboratory data available at this time.

IV. CONCLUSIONS AND RECOMMENDATIONS

The threshold distances for minimal retinal burns reported here are recommended for use as a guide in establishing interim eye safety criteria. They are believed to be a reasonable and realistic assessment of the eyeburn hazard from small nuclear detonations. The method and technic used here have been used successfully in the past to predict experimentally verified threshold distances for animals, although not for the range of yields covered here. Additional work is needed, however, to (1) extend the threshold curves for minimal burns to primates to allow extrapolation to man with more confidence, (2) establish a realistic safety factor and a method of introducing it into the prediction technic used here, and (3) establish a definition of minimum acceptable damage.

Concerning the flashblindness problem, it is recommended that the results reported here be used as an interim guide in establishing operational criteria. It is evident, however, that additional experimental work in this area is needed to (1) establish the relationship

between retinal exposure and exposure time for various recovery end-points, e.g., 5 sec. to read an altimeter, (2) obtain recovery time data in the exposure area where safety considerations preclude the use of human subjects, and (3) establish the ability of trained pilots to control aircraft under various conditions of flashblindness.

REFERENCES

1. Personal communication from Ralph G. Allen, Jr., Technology, Inc. This data was obtained under contract to the USAF School of Aerospace Medicine and partially funded by the Defense Atomic Support Agency.
2. Miller, N. D. Visual recovery. SAM-TR-65-12, Apr. 1965.
3. Ham, W. T., Jr., H. Wiesinger, F. H. Schmidt, R. C. Williams, R. S. Ruffin, M. C. Shaffer, and D. Guerry, III. Flash burns in the rabbit retina: as a means of evaluating the retinal hazard from nuclear weapons. Amer. J. Ophthal., 46: 700-723, 1958.
4. Alder, A. V. C131/T29 flight simulator flashblindness study. SAM-TR-65-75, Oct. 1965.
5. Glasstone, S. (ed). The effects of nuclear weapons. U. S. Atomic Energy Commission, Washington, D. C., U. S. Government Printing Office, Apr. 1962.
6. Geeraets, W. J., R. C. Williams, G. Chan, W. T. Ham, Jr., D. Guerry, III and F. H. Schmidt. The loss of light energy in retina choroid. Arch. Ophthal. (Chicago), 64: 606-615, 1960.
7. Jacobson, J. H., B. Cooper, H. W. Najac. Effects of thermal energy on retinal function. AMRL-TDR-62-96, Aug. 1962.
8. Weymouth, F. W., et al. Visual acuity within the area centralis and its relation to eye movements and fixation. Amer. J. of Optometry and Archives of Amer. Acad. of Optometry, 40: 520-537, 1963.

TABLE I. Exposure time, image diameter, retinal exposure, and retinal irradiance as functions of yield, distance, atmospheric transmission and filter transmission. (Human eye exposed to sea-level air bursts.)

			Bright Daylight		Dim Cockpit	
W (kt)	t (sec.)	D_i (mm.)	Q_r (cal/cm^2)	H_r (cal/cm^2-sec)	Q_r (cal/cm^2)	H_r (cal/cm^2-sec)
0.01	.0064	$\frac{2.50x10^4}{D}$	$788T_aT_x$	$123T_aT_x$	$4.54T_aT_x$	$709T_aT_x$
0.03	.0111	$\frac{3.91x10^4}{D}$	$.982T_aT_x$	$88.5T_aT_x$	$5.65T_aT_x$	$510T_aT_x$
0.1	.0202	$\frac{6.31x10^4}{D}$	$1.25T_aT_x$	$61.7T_aT_x$	$7.19T_aT_x$	$355T_aT_x$
0.3	.0351	$\frac{9.81x10^4}{D}$	$1.56T_aT_x$	$44.3T_aT_x$	$8.96T_aT_x$	$255T_aT_x$
1.0	.064	$\frac{1.59x10^5}{D}$	$1.98T_aT_x$	$30.9T_aT_x$	$11.4T_aT_x$	$178T_aT_x$
3.0	.111	$\frac{2.46x10^5}{D}$	$2.48T_aT_x$	$22.2T_aT_x$	$14.2T_aT_x$	$128T_aT_x$
10.0	.202	$\frac{3.98x10^5}{D}$	$3.13T_aT_x$	$15.4T_aT_x$	$18.0T_aT_x$	$89.0T_aT_x$

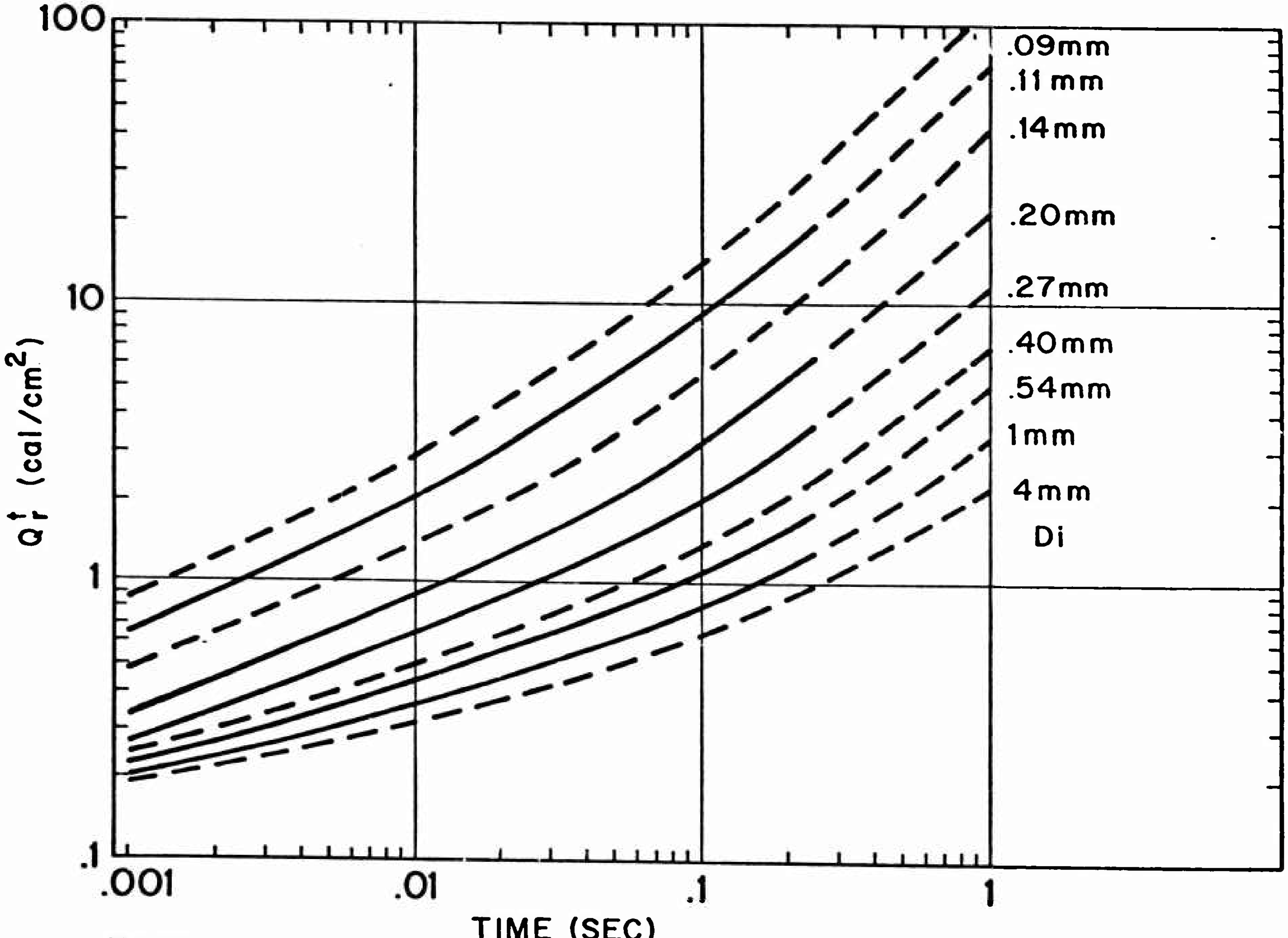

FIGURE 1. Threshold retinal exposure, Q_r^t, versus time for the production of minimal burns in the retina of pigmented rabbits. (Dash lines are interpolated or extrapolated.)

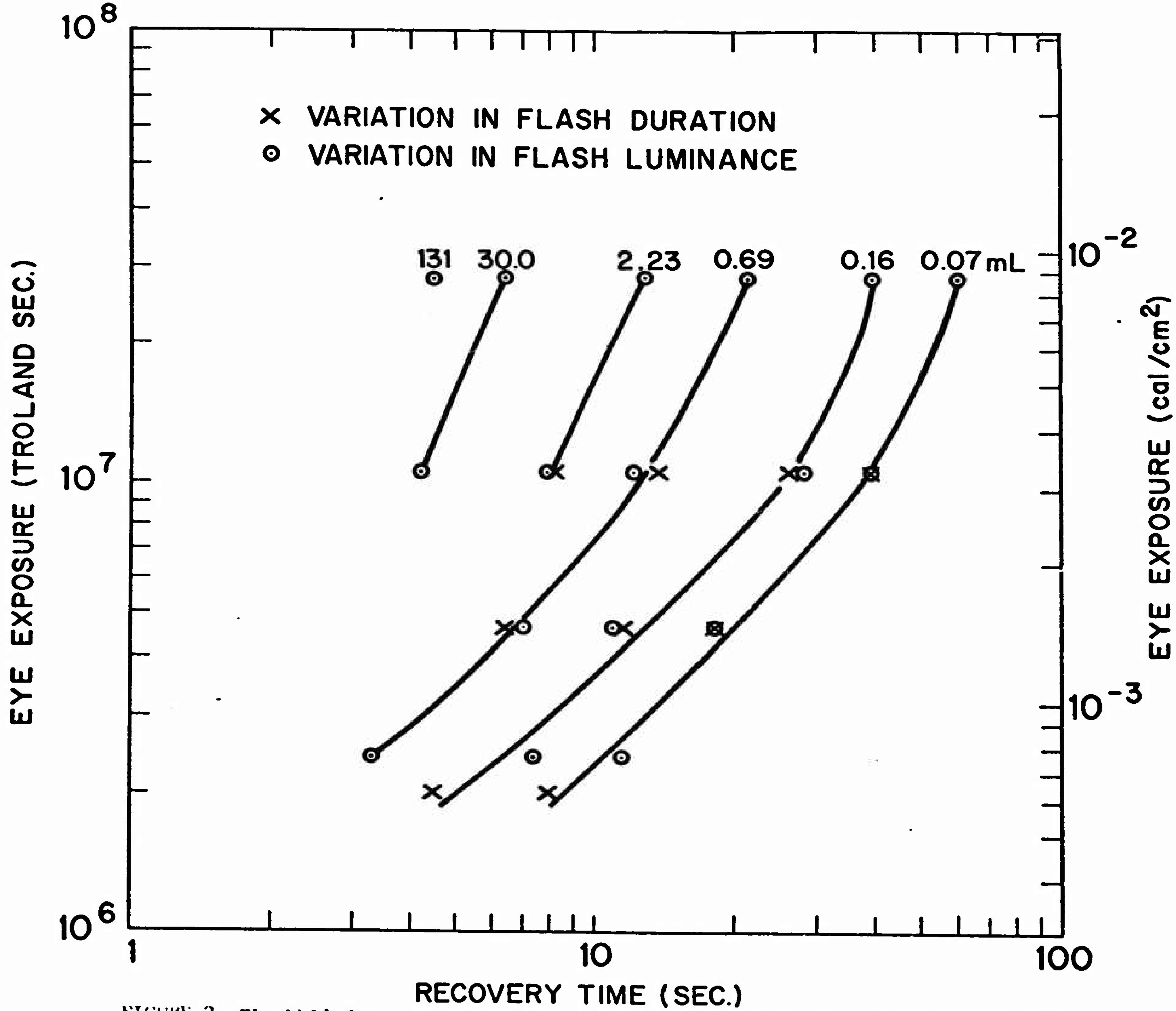

FIGURE 2. Flashblindness recovery time versus eye exposure for a 28.4 minute test letter presented at the indicated luminance levels.

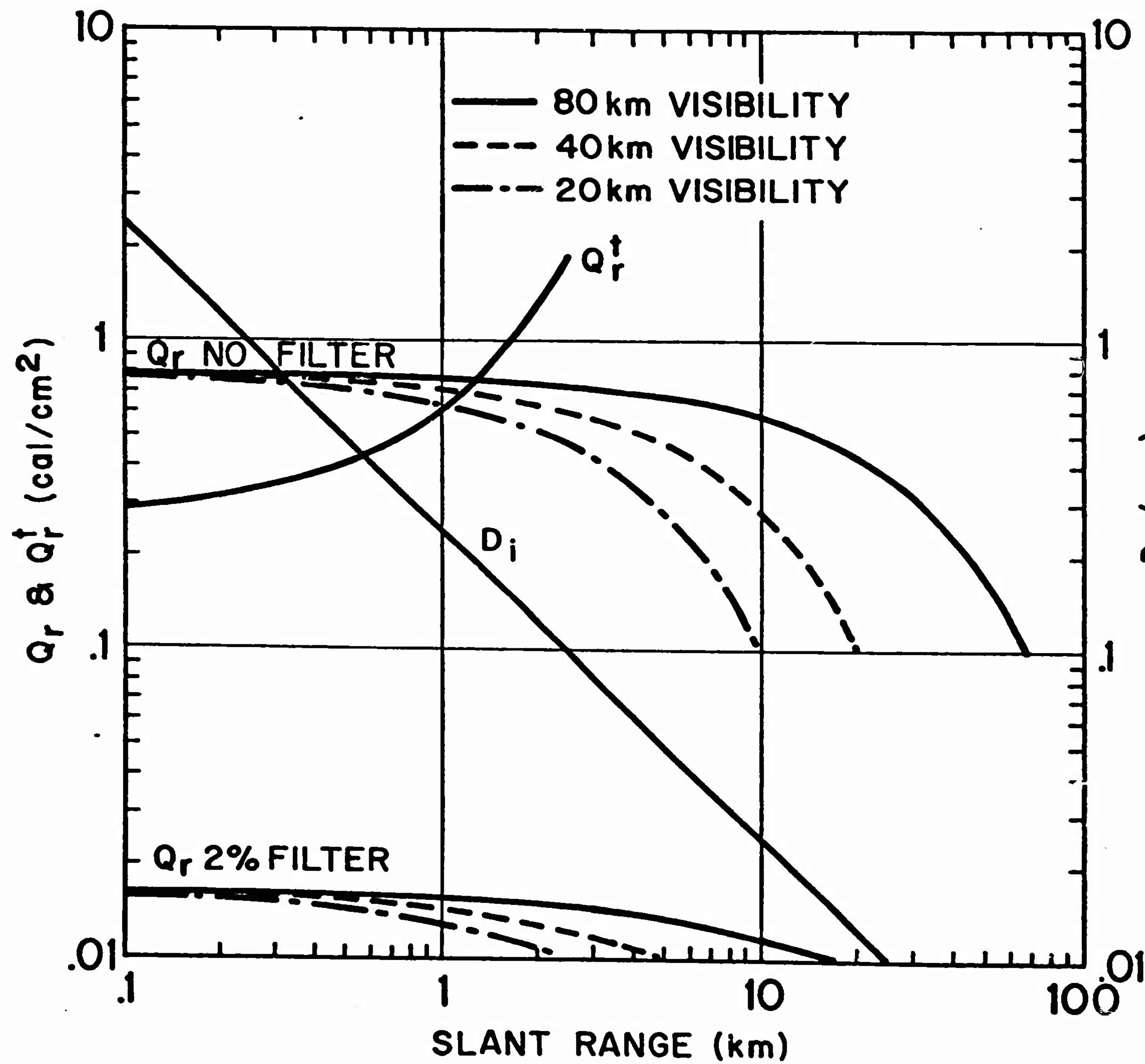

FIGURE 3. Image diameter, D_i, retinal exposure, Q_r, and threshold exposure, Q_r^t, as functions of distance from a 0.01 kt detonation for the human eye in bright daylight. Exposure time is 0.0064 sec.

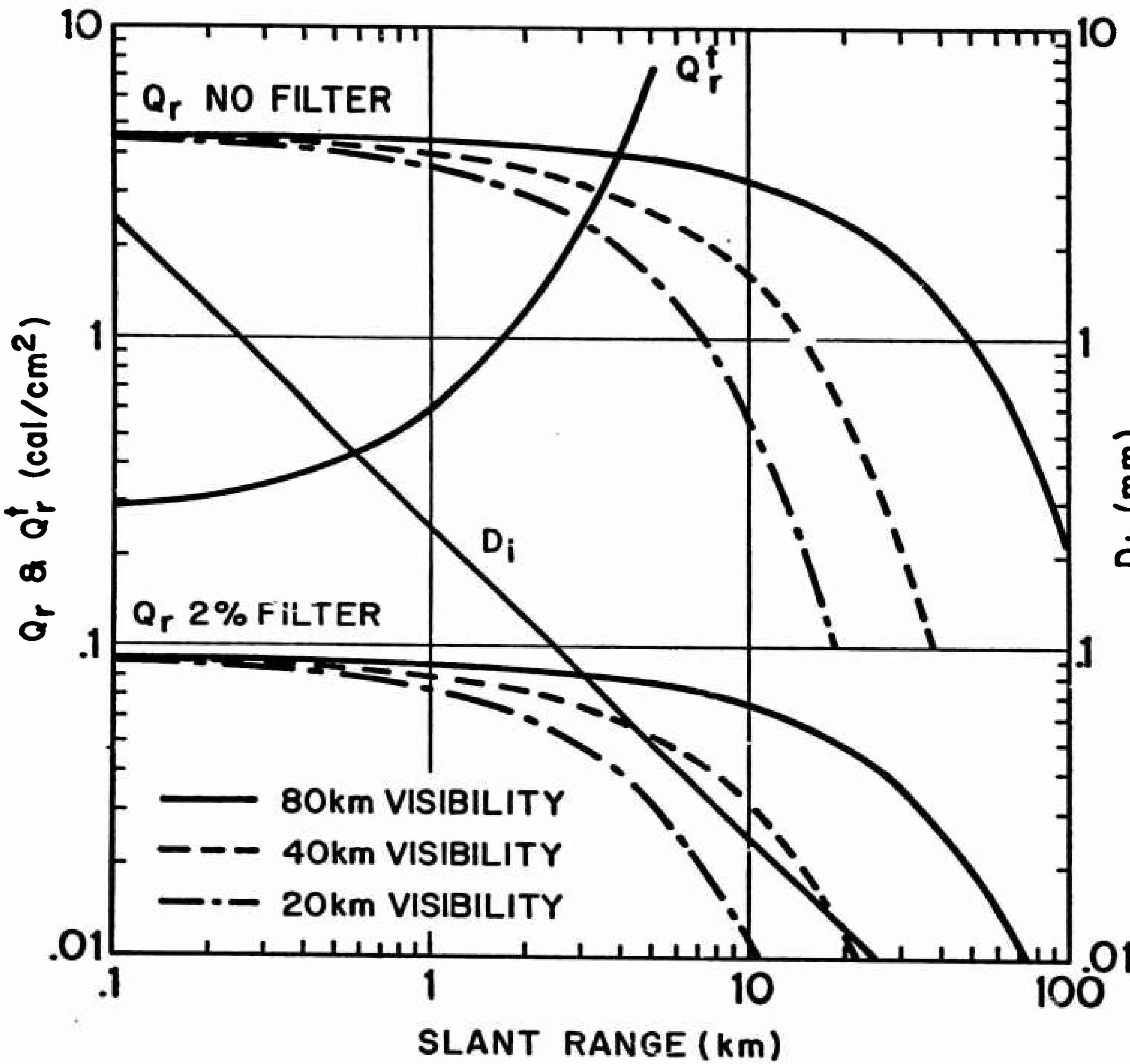

FIGURE 4. Image diameter, D_i, retinal exposure, Q_r, and threshold exposure, Q_r^t, as functions of distance from a 0.01 kt detonation for the human eye at night. Exposure time is 0.0064 sec.

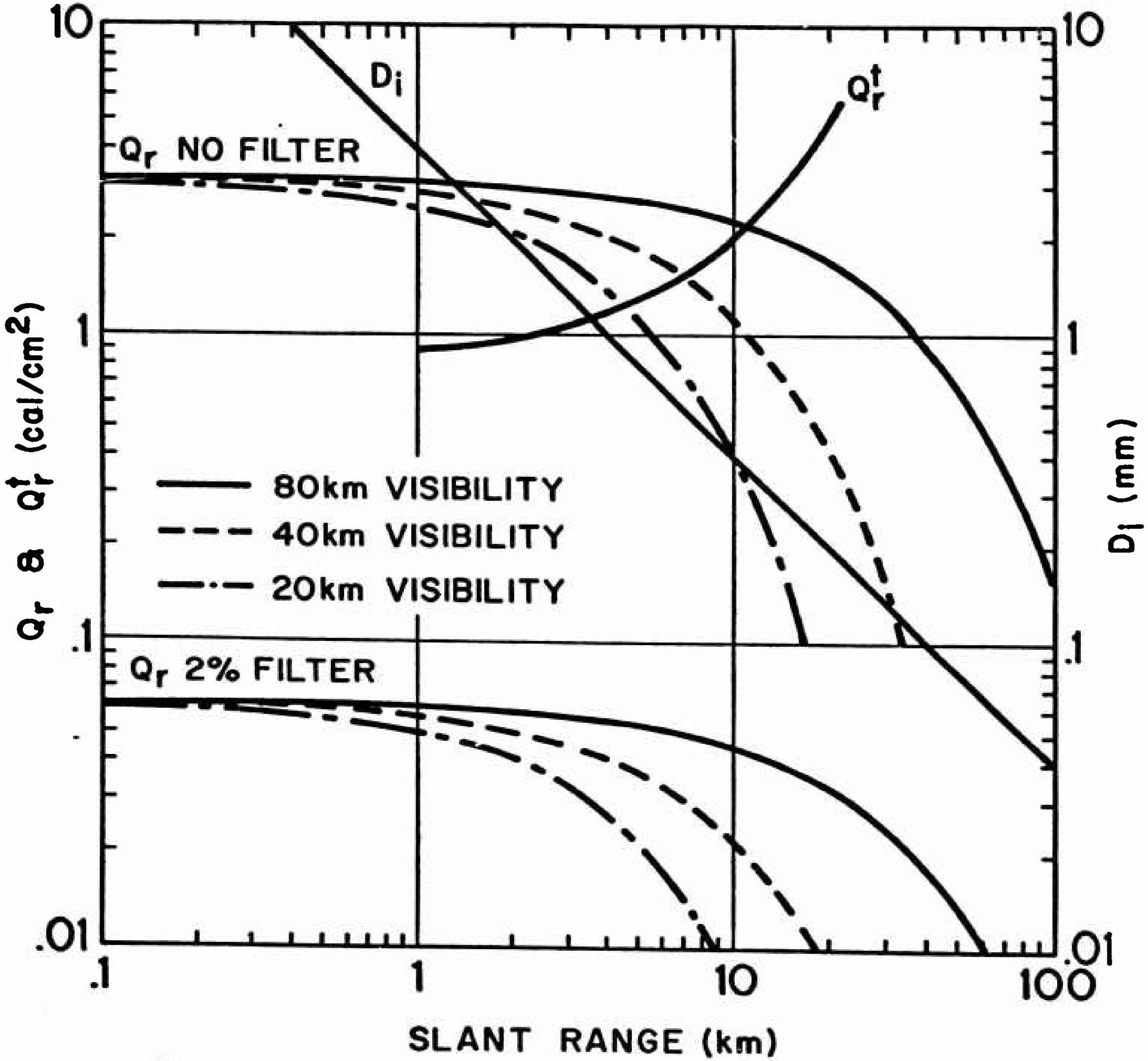

FIGURE 5. Image diameter, D_i, retinal exposure, Q_r, and threshold exposure, Q_r^t, as functions of distance from a 10 kt detonation for the human eye in bright daylight. Exposure time is 0.202 sec.

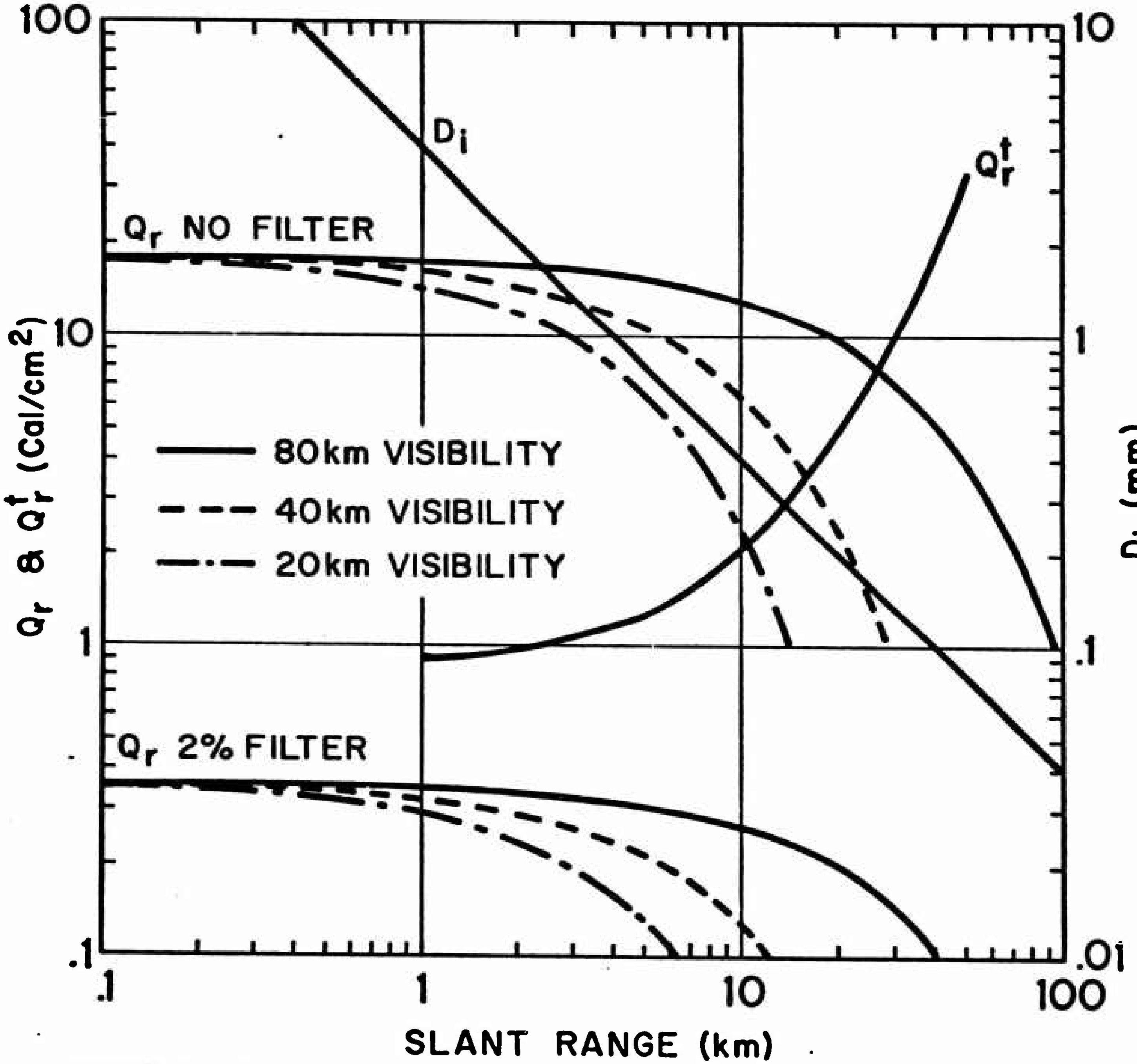

FIGURE 6. Image diameter, D_i, retinal exposure, Q_r, and threshold exposure, Q_r^t, as functions of distance from a 10 kt detonation for the human eye at night. Exposure time is 0.202 sec.

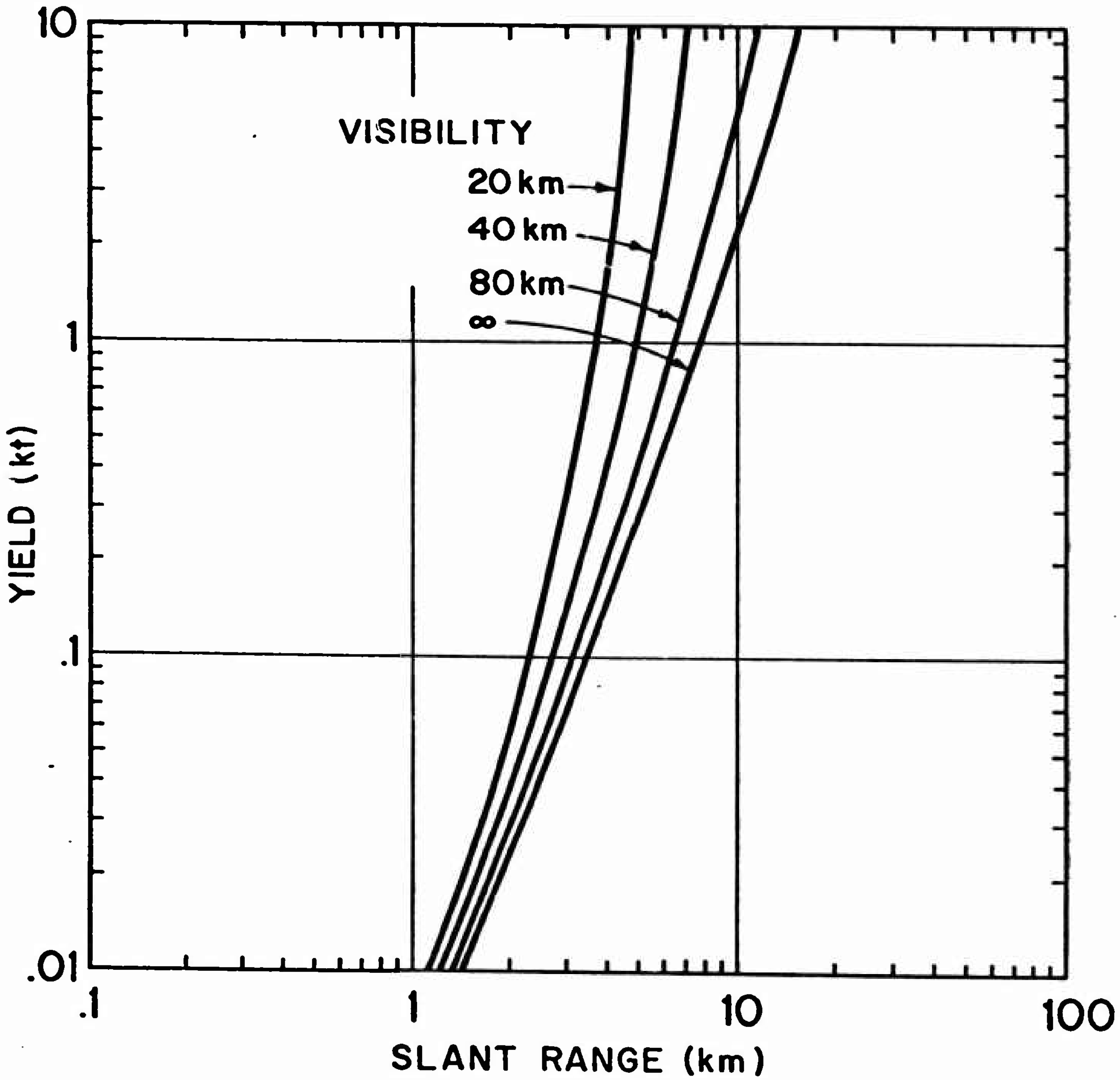

FIGURE 7. Threshold distance for minimal burn versus yield for human eye in bright daylight with no protection.

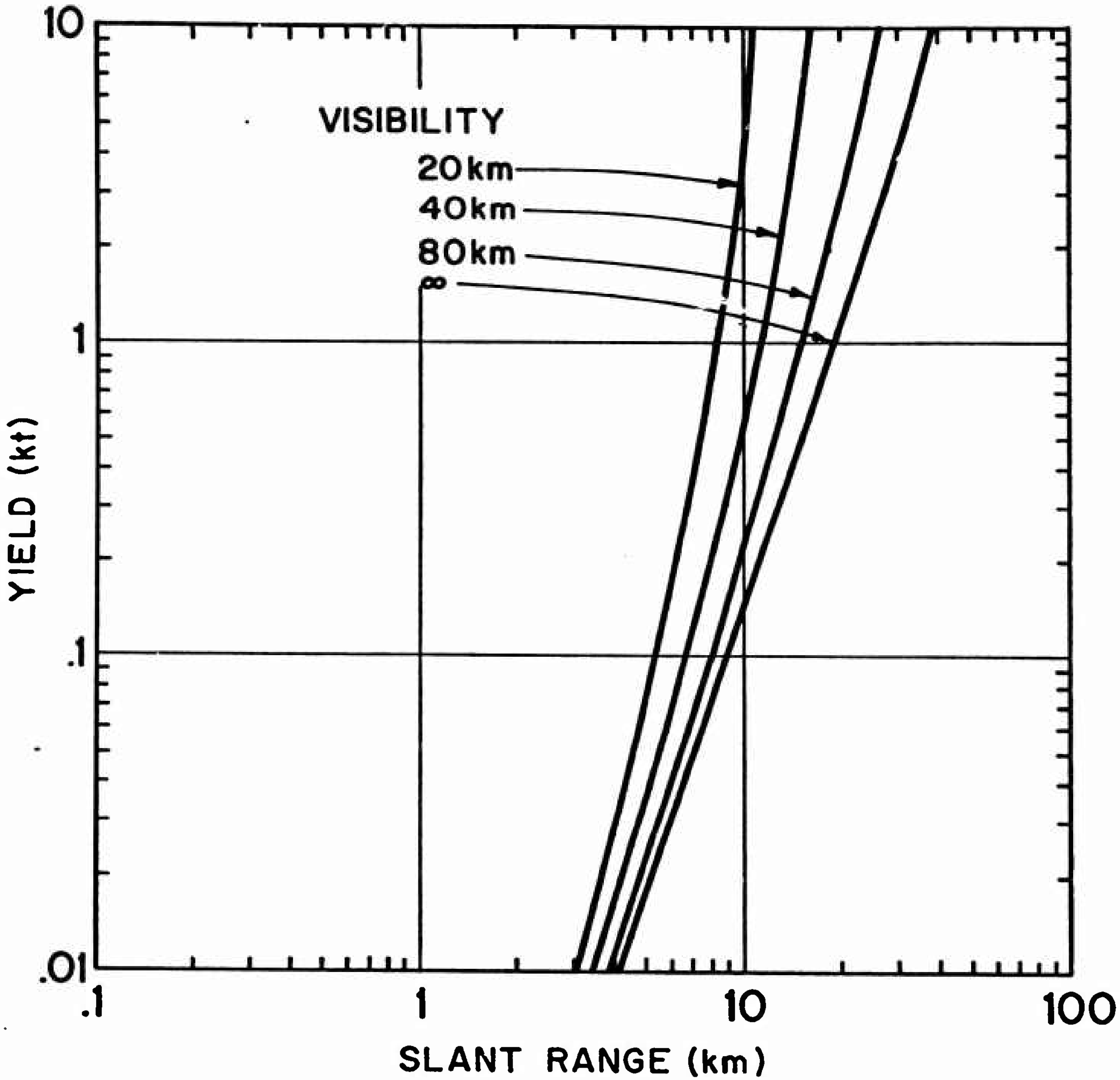

FIGURE 8. Threshold distance for minimal burn versus yield for human eye at night with no protection.

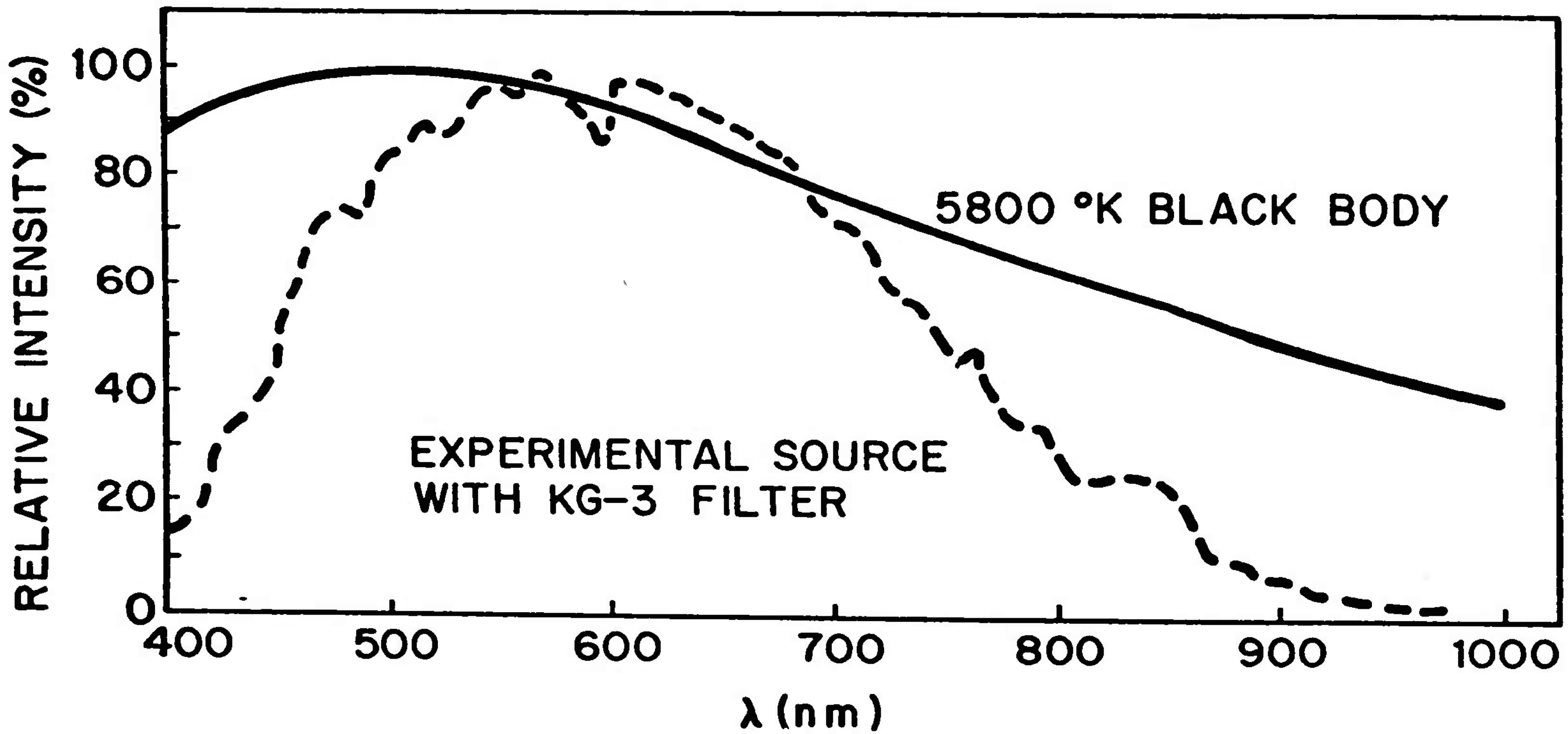

FIGURE 9. Relative spectral distribution of the exposure source used in obtaining the threshold curves in figure 1 compared to the relative spectral distribution of a 5800°K black-body radiator (nm = nano-meters = 10^{-9} meters).

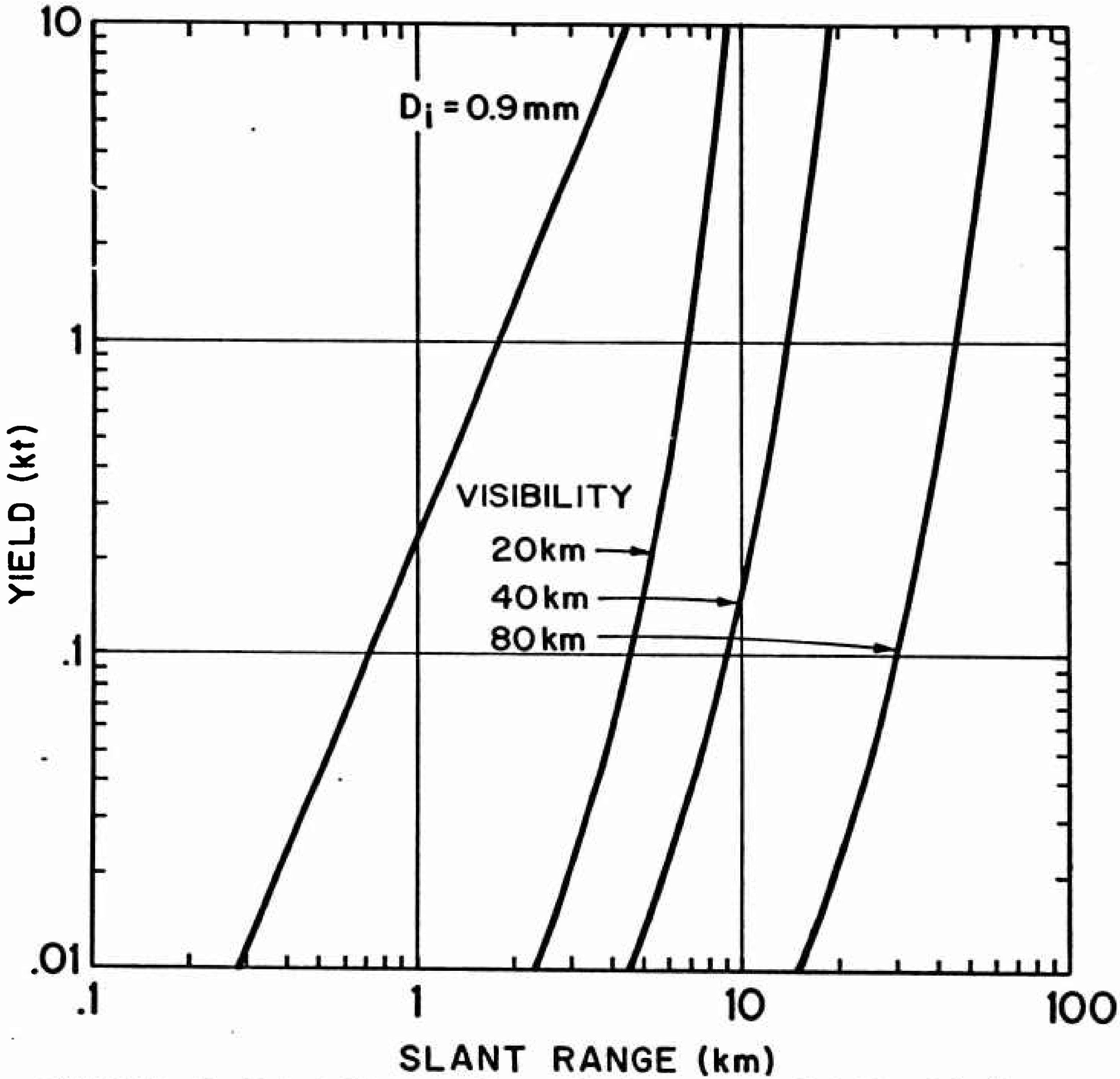

FIGURE 10. Predicted distance for retinal exposure of 0.01 cal/cm^2 versus yield for human eye protected by 2% fixed filter in bright daylight. The D_i = 0.9 mm. line shows the distance versus yield for a fireball image diameter of 0.9 mm.

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13. ABSTRACT

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Eye hazards as a function of distance are determined for the unprotected human eye exposed to sea-level, air-burst detonations from 0.01 to 10 kt yield. The pupil diameter of the human eye is taken to be 2.5 mm. and 6.0 mm. respectively, for day and night conditions and the effective focal length of the eye is taken to be 17 mm. Nuclear detonation characteristics and scaling factors are taken from Glasstone's "The Effects of Nuclear Weapons". The results indicate that the eye hazard is the limiting factor in determining the distance of nearest approach to a nuclear detonation unless eye protection is provided.

Eye hazards as a function of distance are also determined for the human eye protected from daytime detonations by a 2% transmission fixed filter. The results indicate that use of such a filter will provide eye protection at distances where other hazards become limiting factors.

14 KEY WORDS	LINK A		LINK B		LINK C	
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It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, or *(U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.